DISEASES OF SEEDLINGS IN FOREST TREE NURSERIES IN FLORIDA: HISTORY AND STATUS[1]

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ABSTRACT

Important diseases in Florida's forest tree nurseries have included fusiform rust, a "Rhizoctonia blight" of longleaf pine, Phytophtora root rot of sand pine, charcoal root rot, "pitch canker" disease of pines, stem cankers on container-grown eucalypts, brown spot needle blight of longleaf pine, and Phomopsis blight of redcedar. Other diseases of lesser overall impact have included "tip blights" of pine, a root knot nematode - charcoal root rot complex on dogwood, a blight of redcedar caused by Sclerotium rolfsii, Pythium and Phytophthora root rots of dogwood and oaks, and a blight of container-grown longleaf pine caused by Colonectria kyotensis. Other diseases have included miscellaneous nutrient deficiencies and fumigation-induced mycorrhizal deficiencies in vesicular-arbuscular hosts. Nursery-to-field carry-over of nursery-initiated infection has been a focus of attention for a number of host-pathogen combinations. This paper provides a historical overview and current status report for the state's more important forest nursery diseases. Control strategies are also discussed.

INTRODUCTION

Production of seedlings in forest tree nurseries in Florida began in the late 1920's. By the mid 1930's, pine seedling production had arrived in earnest with statewide annual production totaling approximately 14,000,000. By the 1940's, statewide annual production had reached 100,000,000 and annual production peaked in the late 1980's at approximately 195,000,000 seedlings. These figures are inclusive for a constantly changing mix of state-owned, industrial, and private nurseries.

Although 1-0 bare-root pines have accounted for the overwhelming majority of seedlings produced, production has not been limited to pines. Over the years, a number of bare-root nurseries have produced various hardwood species, baldcypress [*Taxodium distichum* (L.) Rich.] and redcedar (*Juniperus virginiana* L.). Also, some nurseries produce crops of containerized seedlings including some ornamental species, but more particularly, and in larger quantities, species of *Pinus* and *Eucalyptus* for afforestation or reforestation.

This paper provides an overview of the more important diseases that have historically

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impacted forest tree seedling quality and production in Florida. Specifics with respect to pathogen biology are minimized because this information is largely available in the phytopathological literature. Instead emphasis is placed upon Florida's forest nursery disease history, experience, management and current situation(s).

HISTORICAL SYNOPSIS

Common and problematic diseases in the "early days" presumably included episodes of damping-off, fusiform rust [caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Hedgc. & N. Hunt) Burdsall & G. Snow], and possibly parasitism of roots by one or more species of plant-parasitic nematodes. In the late 1950's and 1960's, black root rot [caused by a "complex" of *Macrophomina phaseolina* (Tassi) Goid., *Fusarium* spp., and plant parasitic nematodes] and charcoal root rot (caused predominantly, if not strictly by *M. phaseolina*) emerged as major problems (Hodges 1962, Seymour 1969). By the mid 1970's, charcoal root rot was considered the single most serious disease impacting Florida's pine seedling nurseries. Losses to this disease in 1976 were estimated to be at least 20 million seedlings, including an estimated 16.5 million seedlings (approx. value = $148,000.00) quarantined in one nursery alone due to the disease (Seymour and Cordell 1979). This episode resulted in the creation and staffing of the state's first and only forest pathologist position.

Since 1978, attention has been given to a wide variety of seedling diseases, some of which represent major threats to seedling production and others which are only sporadic or situational in their occurrence or ephemeral in nature and cause little impact. Among the more important and impact-producing diseases addressed are fusiform rust, a "*Rhizoctonia* blight" of longleaf pine (*Pinus palustris* Mill.), *Phytophthora* root rot of sand pine [*P. clausa* (Chapm.) Vasey] caused by *P. cinnamomi* Rands, charcoal root rot, "pitch canker" disease of pines, stem cankers on container-grown *Eucalyptus* spp., brown spot needle blight of longleaf pine, and *Phomopsis* blight of redcedar. Episodic nursery diseases of less overall consequence have included root diseases of sand pine caused by *P. nicotianae* B. de Haan var. *parasitica* (Dastur) Waterh., pine "tip blights", a root knot nematode - charcoal root rot complex on dogwood, (*Cornus florida* L.), a blight of redcedar caused by *Sclerotium rolfsii* Sacc. (teleomorph; *Athelia rolfsii* Tu and Kimbrough), *Pythium* and *Phytophthora* root rots of dogwood and oaks (*Quercus* spp.), and a previously unreported blight of container-grown longleaf pine caused by *Calonectria kyotensis* Terashita.

Other "diseases" which have been documented and addressed include miscellaneous nutrient deficiencies and fumigation-induced mycorrhizal deficiencies in a variety of vesicular-arbuscular hosts. Ectomycorrhizal deficiencies, for the most part, have not been problems due to rapid reinfestation of fumigated nursery soils by the common basidiomycetous symbionts *Thelephora terrestris* Ehrh.:Fr., *Rhizopogon nigrescens* Coker & Couch, and in certain situations, *Pisolithus tinctorius* (Pers.) Coker & Couch.

Of particular concern with respect to many of the forest "nursery" diseases mentioned above has been the potential for nursery-to-field carry-over and latent disease development subsequent

to outplanting. Specifically, focus has been directed upon identifying those pathogens that might be associated with such diseases and evaluating their damage potential (Barnard 1984; Barnard 1994; Barnard *et al.* 1985b)

THE CURRENT SITUATION

The following are brief status reports on Florida's more important and interesting forest nursery diseases. Approaches to disease management and control are discussed.

Damping-Off

Major damping-off problems in Florida's forest tree nurseries are infrequent. Several factors may account for this desirable situation. Among such factors are: (1) the generally sandy, well-drained nature of Florida's bare-root nursery soils, (2) environmental conditions conducive to rapid seed germination, (3) the routine utilization of quality, pathogen-free seed, (4) seed treatments such as thiram, and (4) the maintenance of innocuous populations of soilborne pathogens through intelligent crop rotations and periodic soil fumigation with methyl bromide or other soil sterilants. Damping-off in containerized nursery operations is minimized through the use of pre-sterilized or pathogen-free potting mixes.

In cases where problematic levels of damping-off have occurred and been evaluated, common soilborne damping-off pathogens including species of *Pythium*, *Rhizoctonia* (or *Rhizoctonia*-like fungi), and *Fusarium* are often detected. In some cases, the charcoal root rot pathogen, *M. phaseolina*, has been implicated, but this is not particularly common. Interestingly absent from the pathogen mix have been species of *Phytophthora*.

Fusiform Rust

Although this disease is considered the most serious disease impacting southern pine forestry (especially the intensive culture of *Pinus taeda* L. and *P. elliottii* Engelm.) in both nurseries and plantations, surprisingly little is actually known regarding the annual impact of fusiform rust in Florida forest nurseries. In part, this information gap is due to (1) the traditionally excellent fungicidal control programs employed by nursery managers (formerly ferbam-, currently triadimefon-based) and (2) the lack of unprotected impact assessment or monitoring plots in operational nurseries (nursery managers spray all seedlings; no unsprayed seedlings are evaluated). However, the potential for catastrophic losses was dramatically emphasized in one Florida nursery in 1979 where incidence was so high (approx. 75-80% of seedling stems infected across one nursery block) that some 7.5 million seedlings valued at approximately $97,000 were destroyed. This incident occurred despite repeated prophylactic applications of the contact fungicide ferbam. Since the early 1980's and the introduction of triadimefon fungicide for control of fusiform rust in forest nurseries (Carey and Kelley 1993; Kelley 1985; Kelley and Runion 1991; Powers 1984; Rowan 1982a; Snow *et al.* 1979), losses have been minimal.

Charcoal Root Rot

At one time clearly considered among Florida's most serious forest nursery diseases, charcoal root rot has diminished in severity in recent years. Nursery managers have, for the most part, adopted management strategies which minimize the potential for serious disease losses. Such strategies include avoidance of cover crops (such as legumes) which enhance buildup of soilborne *M. phaseolina* populations, minimizing water stress to seedlings during high temperature periods or following root pruning or undercutting, and soil fumigation.

Historically, charcoal root rot has been considered a serious pine seedling disease (Barnard and Gilly 1986; Hodges 1962; Rowan 1971; Seymour 1969; Seymour and Cordell 1979). However, *M. phaseolina* is probably at best an opportunistic pathogen, responsive to soil fertility levels, irrigation, soil temperatures, plant stress and senescence (Dhingra and Sinclair 1978; Hodges 1962; McDonald and Mehan 1984; Reuveni and Madar 1985; Watkins 1981; Wylie 1989). Indeed, this author has witnessed "charcoal root rot"scenarios in pine nurseries only in association with cultural practices or conditions which could be viewed as suspect and where seedlings have been subjected to unnecessary stress (untimely and purposely induced water stress to "harden-off" seedlings, root pruned seedlings subjected to excessive water-stress, etc.). Accordingly, the question may be asked, "Is this a biotic disease caused by a serious pathogen, or a biotic response to ill-advised or accidental nursery management or mismanagement?"

For some time, pine seedling outplant failures, often on agricultural lands in Florida, were often attributed to nursery-originated *M. phaseolina* infections because this organism was sometimes detected on seedlings that died following outplanting. This "nursery linkage", unfortunately, was often more a function of nursery reputation and a presumed understanding of the biology of the pathogen than hard core evidence *per se*. Such interpretation(s) enhanced the belief that *M. phaseolina* was a serious nursery pathogen. Recent evidence, however, reinforces the relatively cosmopolitan distribution of *M. phaseolina*, especially in Florida agricultural soils, and the organism's role as a stress-responsive secondary colonizer (Barnard *et al.* 1995; Barnard *et al.* 1994a). Further, attempts to simulate nursery-to-field carry-over of *M. phaseolina* on the roots of asymptomatic seedlings suggest that, although such transport is possible, it may not occur at high frequency or be a management concern (Barnard 1994).

Phytophthora Root Rots of Sand Pine

Sand pine is a relatively small, short-lived southern yellow pine native to Florida's sandhills. This species makes up a small component of Florida's commercial forestry mix, but it is still produced in some forest tree nurseries. It is used primarily for Christmas trees and on sites unsuitable for the more popular slash and loblolly pines.

Historically, sand pine has been plagued by serious root disease problems including both nursery and plantation infections by *Phytophthora cinnamomi* (Barnard *et al.* 1985a; Barnard 1988; Ross and Marx 1972). *P. cinnamomi* infections are serious on sand pines which are apparently innately susceptible to root disease infections in general. Infected trees usually succumb at an

early age. Although differences in susceptibility between the Choctawhatchee variety (*P. clausa* var. *immuginata* Ward), native to Florida's western panhandle, and the Ocala variety (*P. clausa* var. *clausa* Ward), native to peninsular Florida, have been reported (Barnard *et al.* 1993; Ross and Marx 1972), such differences are inconsistent and nursery managers, foresters and landowners cannot rely upon apparent "resistance" to avoid losses. Evidence is strong that many *P. cinnamomi* disease scenarios in sand pine plantations are a function of nursery-to-field carry-over of the pathogen on the roots of outplanted seedlings (Barnard *et al.* 1985a; Barnard *et al.* 1985b).

Of lesser importance, and perhaps only significant as mycological or pathological curiosities, have been ephemeral root rots and associated mortality of sand pine seedlings "caused" by *P. nicotianae* var. *parasitica*. Three episodes of this host-pathogen association have been documented in Florida forest nurseries; two in bare-root nurseries and one in a containerized nursery. In each case, seedling mortality was rapid and occurred in the heat of Florida's mid growing season (July - September) in water-saturated or puddled soils. Disease spread in affected seedbeds or containers was minimal and was apparently arrested with the onset of improved soil drainage. *P. nicotianae* var. *parasitica* has not been detected on planted or naturally established sand pines in field situations.

"Conventional wisdom" might suggest that *Phytophthora* root rots of sand pine could be controlled by soil fumigation with methyl bromide. However, every case of such infections known to this author in Florida forest nurseries has occurred in fumigated soils. Indeed, in the one Florida nursery with a documented resident population of *P. cinnamomi* (Barnard *et al.* 1985b) there is evidence (author - unpublished) that the pathogen survived in fumigated seedbeds at depths beneath the influence of routine fumigation. Also, the high clay content in the soil at this nursery may have restricted the efficacy of soil fumigation (pathogen surviving in soil clods, etc.). In the case of *P. nicotianae* var. *parasitica*, it is possible that inoculum of the pathogen may be introduced via irrigation water, or it too may survive beneath the zone of fumigation influence.

Phytophthora root rots in Florida forest nurseries today are generally inconsequential. The only nursery with a history of *P. cinnamomi* has not produced sand pine for nearly a decade and in fact is now closed. The remaining nurseries are apparently *P. cinnamomi* - free, contain sandy, adequately drained seedbeds, and are well managed. Whether or not soil fumigation, routinely practiced by most Florida nurserymen, is important in controlling Phytophthora root diseases is really unknown.

Phytophthora and Pythium Root Rots of Hardwoods

Although not a major problem, root rots (as opposed to damping-off) of hardwood species caused by *Phytophthora cinnamomi* and *Pythium* spp. have occurred in Florida forest nurseries. In every case known to this author, infections have occurred in methyl bromide-fumigated seedbeds in areas where shallow clay layers have impeded soil drainage. Infections appeared to have started in tap and lateral roots penetrating soil beneath the influence of the soil fumigant. Hosts affected have included *Cornus florida*, and *Quercus* spp.

"*Rhizoctonia* Blight" of Longleaf Pine

This disease, sometimes referred to as "sand splash" (Davis 1941), has caused serious losses of longleaf pine seedlings in both bare-root and containerized nurseries in Florida. Formerly attributed to *Rhizoctonia solani* Kuhn (Barnard 1979), we now know the disease is caused primarily by a binucleate *R. solani* - like fungus belonging to anastomosis group 3 (CAG 3) of the genus *Ceratobasidium* (English *et al.* 1986). On one occasion, a similar infection (*i.e.*, foliage blight), apparently caused by the same organism, was documented on loblolly pine in a Florida nursery, but the primary occurrence remains on longleaf pine due largely to the "grass stage" seedling habit of the latter.

Fungicides have proven relatively unsatisfactory to control this disease in Florida. Nursery managers have mostly relied on cultural approaches to minimize losses. Fall sowing of longleaf pine seed, together with carefully selected, well timed, and repeated seedbed mulches generally provide adequate disease control (Barnard *et al.* 1994b; Davis 1941; Gilly *et al.* 1985; Davis 1941). Soil fumigation appears to give some measure of control, but pathogen inoculum sources are not well defined.

"Pitch Canker" Disease of Pines

Fusarium subglutinans (Wollenw. & Reinking) Nelson, Toussoun & Marasas causes a distinctive canker and dieback disease on a variety of *Pinus* spp. (Barnard and Blakeslee 1980; Blakeslee *et al.* 1980; Dwinell *et al.* 1985). This fungus is also capable of infecting pine cones and seed and can cause seedling infections ranging from pre- and post-emergence damping-off to tip-blight, root rots, lethal stem cankers and root collar lesions. "Pitch canker" was first reported in 1980 in Florida as a "new" nursery disease of slash pine (Barnard and Blakeslee 1980). Since that time it has appeared periodically in various pine seedling crops. Fortunately, seedling losses to "pitch canker" infections are typically inconsequential in most crops (< 1-5%), although substantially higher losses (10-15%) have been recorded for certain slash pine crops on a seedlot by seedlot basis (G.M. Blakeslee - personal communication). Slash pine is the primary species affected by *F. subglutinans* in Florida nurseries, but infections also occur on sand and longleaf pines. Fungicides are ineffective for control (G. M. Blakeslee - personal communication). For the most part, disease impact is minimized through use of resistant seed sources, sound seed orchard management and clean seed handling and processing procedures, ensuring pathogen-free, high-quality seed.

Nursery-to-field carry-over of "pitch canker" infections are of concern to nursery managers and foresters in Florida, primarily because seedling infections are typically lethal. Field observations and preliminary studies (Barnard - unpublished, G. M. Blakeslee - personal communication) provide evidence supportive of a nursery-to-field carry-over linkage, but definitive research is still wanting.

Brown Spot Needle Blight

Brown spot needle blight, caused by *Mycosphaerella dearnessii* Barr [= Scirrhia acicola (Dearn.) Siggers], has caused serious losses in longleaf pine seedling crops in forest nurseries in Florida's western panhandle. Production of longleaf pine in these nurseries requires a rigorous fungicidal protection program using primarily chlorothalonil and/or benomyl. Brown spot-free seedlings are necessary for regeneration programs since nursery-initiated infections can intensify under field conditions, resulting in mortality or poor performance. Most of Florida's nursery production of longleaf pines is now located in the state's northern peninsular region where disease pressure is less intense than it is in the panhandle region. Concomitantly, current losses to brown spot infections are minimal, and the need for judicious fungicidal protection has been obviated.

Pine Tip Blights

The periodic occurrence of pine seedling "tip blights" in Florida's forest nurseries causes concern to nurserymen from time to time. Described as "tip dieback" by Rowan (1982b), these phenomena are apparently caused by a variety of fungi. Rowan reported that *Fusarium subglutinans*, *Lasiodiplodia theobromae* Pat. (= *Diplodia gossypina* Cke.) and a *Phomopsis* sp. were all capable of inducing symptoms when artificially inoculated onto the wounded terminals of 1-year-old loblolly pine seedlings. These, and a number of other fungi (some of uncertain taxonomic affinity), including on one occasion *M. phaseolina*, have been associated with tip blight scenarios on pines in Florida forest nurseries over the years (author-unpublished). It appears that tip blight phenomena are the result of opportunistic infections by a variety of fungi that take advantage of warm, humid environmental conditions and the tender, succulent growing shoots of young pines abundantly provided in forest tree nurseries. Evaluations in Florida (author - unpublished) indicate high levels of tip blight to be associated with nursery locations prone to moisture and humidity buildup and/or retention (low spots or depressions in seedbeds) and seedling crops exhibiting particularly rapid development (thus, elongated tender, succulent growing shoots). Field observations have also revealed essentially full recovery of blighted seedlings within 30 days following the onset of visual symptoms. Tip blights of this nature appear to be more an ephemeral phenomenon than a disease of consequence.

Cylindrocladium Stem Cankers of *Eucalyptus* spp.

In the 1970's and early 1980's, the Florida Division of Forestry produced several million containerized eucalyptus seedlings for commercial forestry plantings in south-central peninsular Florida. Peak production reached approximately two million seedlings per year in the late 1970's. *Eucalyptus* production was terminated in 1982-83 due to a series of damaging freezes and changing forestry priorities. However, during the period of *Eucalyptus* production, *Cylindrocladium scoparium* Morgan surfaced as a major forest nursery pathogen in Florida. This organism, already well known as a pathogen of *Eucalyptus*, especially in South America, caused major losses in crops of *E. grandis* Hill ex Maid. and *E. robusta* Sm. in a containerized

nursery in Highlands Co. (south-central peninsular Florida) by inducing distinctive and often lethal girdling stem cankers (Barnard 1984). A fungicide trial (Barnard 1984) showed chlorothalonil and benomyl to provide effective control, but emphasis was ultimately placed on changing cultural protocols such as improving container spacing and aeration and reducing irrigation. A field outplant trial (Barnard 1984) demonstrated that the pathogen had little residual effect on seedlings once they were planted onto field sites. Only seedlings with advanced stem cankers in the nursery failed to perform well once outplanted. The pathogen acted aggressively only in the nurseries characterized by closely spaced, poorly aerated, and heavily watered seedlings in a warm, humid environment.

Calonectria Blight of Containerized Longleaf Pine

As eucalyptus production subsided in the early 1980's, the Florida Division of Forestry increased production of containerized pine seedlings. Production was initially centered in the Division's Highlands Co. (south-central Florida) container nursery facility. In 1985, a foliage blight ravaged the containerized longleaf pine crop, destroying thousands of seedlings. Field and laboratory analyses established a clear association between the damage and *Calonectria kyotensis* Terashita (anamorph; *Cylindrocladium floridanum* Sobers & C.P. Seymour). Isolations from necrotic pine needles consistently yielded the distinctive anamorph, and characteristic perithecia of the teleomorph were observed in profusion on symptomatic tissues in the field. Kochs postulates were not completed for this apparently unreported host-pathogen association. However, the characteristic pathogenicity of *Cylindrocladium* (and *Calonectria*) spp. on a wide variety of hosts growing in closely spaced, poorly aerated, hot, humid environments and a consistent association between disease symptoms and the isolated organism leave little doubt as to the causal relationship.

Cultural practices including improved seedling container spacing, judiciously timed clippings of longleaf pine seedling needles, together with a fungicidal protection program consisting of alternating sprays of chlorothalonil and benomyl provided adequate protection for subsequent seedling crops into the early 1990's. In 1993, the Division of Forestry relocated its containerized nursery operation into northern Florida (Levy County). This move has apparently provided a fortuitous escape from the *Calonectria/Cylindrocladium* inoculum and associated disease pressure.

Blights of Redcedar

Redcedar (*Juniperus virginiana*) was a significant seedling crop in Florida forest nurseries until very recently. Despite recent decreases in overall production, some forest nurseries still produce large numbers of bare-root seedlings. In certain nurseries, these crops have been periodically ravaged by *Phomopsis juniperovora* Hahn, necessitating consistent fungicidal applications using primarily thiophanate methyl and zinc ion + maneb.

In one nursery, serious seedling losses were once attributable to a blight caused by *Sclerotium rolfsii* Sacc. [teleomorph; *Athelia rolfsii* (Curzi) Tu & Kimbrough]. This-host-pathogen

relationship, although apparently not unknown, was unusual in a forest nursery. Roguing infected seedlings, and removing substantial buffers of asymptomatic seedlings around infection foci was successful in reducing losses.

Root Knot Nematode - *Macrophomina* Complex on Dogwoods

Through the 1970's and into the 1980's, flowering dogwoods (*Cornus florida*) were routinely produced as bare-root seedlings in state-owned forest nurseries in Florida. Today, dogwood seedling production is handled predominantly by the private sector. In 1981, serious damage was inflicted upon one dogwood crop by a root knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood] - *M. phaseolina* complex (Barnard *et al.* 1982; Lehman and Barnard 1982). Losses of about 180,000 seedlings valued at more than $10,000 resulted. The disease occurred once and was restricted to a nursery area that had not been fumigated immediately prior to sowing.

Anthracnose of Acacia

At one time, the Florida Division of Forestry produced a wide variety of container-grown seedling species for urban landscape beautification. Under warm, humid conditions, close seedling spacings, and frequent irrigation, anthracnose caused by *Colletotrichum gloeosporioides* (Penz.) Sacc. [teleomorph; *Glomerella cingulata* (Stonem.) Spaulding and Schrenk] became a serious problem (Barnard and Schroeder 1984) on *Acacia* spp. grown at a container nursery in Highlands County (south-central Florida). Chlorothalonil provided some control, but losses were mostly reduced by lowering seedling densities and reducing irrigation.

Mycorrhizae

Artificial inoculations with selected mycorrhizal fungi are not operational procedures in Florida's forest tree nurseries. Experimental inoculations with the ectomycorrhizal symbiont *Pisolithus tinctorius* have been conducted in several pine nurseries with variable results. However, rapid and abundant colonization of Florida nursery soils by *Thelephora terrestris*, *Rhizopogon nigrescens*, and sometimes *P. tinctorius* has obviated any need for artificial inoculation of pine seedling crops for routine afforestation or reforestation. Although suppression of ectomycorrhizal development on pine seedlings sprayed with triadimefon for control of fusiform rust is commonplace (Marx *et al.* 1986), negative effects on overall seedling development and field performance have not been demonstrated.

Deficiencies in vesicular-arbuscular mycorrhizae (VAM) and associated reduced seedling growth have been documented for a variety of endomycorrhizal tree species in fumigated nursery seedbeds (author - unpublished). Tree species affected included *Acer rubrum* L., *Liquidambar styraciflua* L., *Cornus florida*, and *Juniperus virginiana*. Deficiencies are typically present in seedbed soils fumigated immediately prior to seed sowing. Fumigation and growing a suitable cover crop several months to a year prior to sowing seed have proven beneficial for alleviating

VAM deficiencies

Heat Lesions

Periodically in Florida, forest nursery seedlings suffer damage as a result of high groundline temperatures and resulting groundline heat lesions (Barnard 1990). Damage often occurs on young, germinating or recently germinated seedlings, but older seedlings can also be affected. The frequency and severity of damage is clearly related to high spring and early summer temperatures. Damaged seedlings are often killed. Occurrence of damaging groundline temperatures is related not only to ambient air temperatures, but also to levels of groundline insolation, soil moisture, color of the soil surface, and irrigation patterns. For example, major seedling losses were sustained recently in one Florida forest tree nursery, apparently because of heat damage related to a dark-colored, heat-absorbing seedbed mulch.

Nutrient Deficiencies

Crop-damaging nutrient deficiencies are rare in Florida's forest tree nurseries. Although Florida's typically sandy forest nursery soils are innately prone to deficiencies, fertilization programs are sophisticated and judiciously applied.

Always of concern to Florida's nurserymen is the maintenance of a suitable pH in nursery seedbed soils. High levels of basic cations (especially Ca) are usually found in irrigation water from wells drawing from limestone aquifers. Therefore, soil pH easily becomes alkaline. As a result, soil pH values in excess of 6.0 are not uncommon and contribute to micronutrient deficiencies, especially Fe and Mn. These pH-induced deficiencies are usually recognized quickly and treated with appropriate soil amendments, such as sulfur and micronutrient fertilizers.

One little known and novel micronutrient deficiency which has occurred in Florida forest nurseries is boron deficiency. This infrequent, but problematic deficiency has been documented in one Florida nursery (Stone *et al.* 1982) and is believed to have occurred in two others (author - unpublished). Affected pine seedlings (*P. taeda*; *P. elliottii*) exhibit dysfunctional and necrotic, sometimes resin-impregnated terminal buds. Outplanted seedlings initiate growth with a pronounced lack of apical dominance, resulting in a bush-like appearance. Although effects of boron deficiencies can be pronounced and serious, deficiencies in well managed nurseries are rare and usually avoided by maintaining a suitable soil pH and adhering to a systematic micronutrient fertilization program.

APPROACHES TO DISEASE MANAGEMENT

Forest tree nursery disease management in Florida is a constant concern. Like so many other aspects of nursery management, disease management strategies are continuously evaluated and subject to periodic change. Changes in approaches to disease management have

been directed by improved understanding of pathogen and disease biology, economics, and environmental considerations. Perhaps the single most important stimulus to the search for improved understanding of forest tree nursery disease biology and alternative strategies for disease control has been the U.S. Environmental protection Agency's (EPA) proposal to ban the production and use of methyl bromide pursuant to the United States' Clean Air Act of 1990 (and in response to the 1991 Montreal Protocol) (Civerolo *et al.* 1993; Smith and Fraedrich 1993). For some, EPA's edict has invoked a measure of consternation, while for others it represents simply another challenge to overcome. In the opinion of this writer, Florida's forest tree nursery disease history provides a base for optimism with respect to the possibilities for alternative strategies. Indeed, some of the more effective strategies for disease management in Florida forest nurseries have been approaches other than "spray it, gas it, or kill it." The need for research on forest nursery diseases, insects and weeds remains great, but there is little reason to fear an "altered" future.

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